Impact of Urban Containment Policies on Public Transit: A Study of the 25 Largest US Metropolitan Areas

by

Corey A. Teague

A Masters Project submitted to the faculty
of the University of North Carolina at Chapel Hill
in partial fulfillment of the requirements
for the degree of Master of Regional Planning
in the Department of City and Regional Planning.

Chapel Hill

2007

Approved by:

_________________________ READER (optional)

_________________________ ADVISOR

Abstract

The impacts of urban containment policies on transportation outcomes have only recently begun to be explored. This study focuses specifically on the impacts of urban containment policies on per capita transit use and supply for the largest 25 US metropolitan areas between the years 1984 and 1994. The analysis relies on a 3SLS fixed effects model for balanced panel data due to the endogenous relationships between population density, transit use, and transit supply. The results suggest that higher rates of urban containment policy coverage in metropolitan areas are related to an increase in per capita transit use and a decrease in per capita transit supply. Additionally, the impacts of urban containment policies are found to increase over time, although at a decreasing rate. The findings, some unexpected, point toward the complex nature of the relationship between land use policies and transportation outcomes, and opens the door for more rigorous empirical work.

Table of Contents

I.	Introduction……………………………………………	1
II.	Prior Research………………………………………	2
III.	Research Approach…………………………………	7
IV.	Data…………………………………………………	8
V.	Methodology………………………………………..	10
VI.	Results and Discussion……………………………..	15
VII.	Conclusions and Limitations……………………….	20
VIII.	References………………………………………….	22

Introduction

This research analyzes the impact of urban containment policies (UCPs) on public transit in urban areas across the United States in terms of use and supply. The goal of UCPs is to curtail the negative effects of sprawling, inefficient development by limiting growth on the periphery and encouraging more development within existing or designated urban growth areas. The policies used to achieve this goal include urban growth boundaries, urban greenbelts/buffers, adequate public facilities ordinances, and others. While many of these strategies are initiated purely at the local level, regional collaboration occurs in some areas, and several states require some form of growth management planning that usually includes one or more UCPs.

While environmental and fiscal benefits of more confined, efficient development are most heavily touted, there are potential transportation benefits as well. Increasingly compact development may generate greater mode choice, which may result in greater mobility, greater accessibility, and fewer vehicle miles traveled (VMT). Reducing or substituting VMT with other modes has perhaps the most diverse range of effects. Increasing urban population densities play an important role in this process. Holtzclaw (1990) found that transit travel of just one mile in higher density areas equals four to eight VMT in less dense areas to accomplish the same daily tasks. Additionally, the ability to walk and bike to more destinations offers a way to incorporate physical activity into daily routines, though this does not necessarily translate into a net increase in physical activity (Khattak and Rodriguez, 2005). Beyond physical activity, greater mobility and accessibility also have multiple positive effects on issues of equity and social justice.

One fairly new program that demonstrates these benefits is the location-efficient mortgage (LEM), currently used in several test markets. This lending tool permits higher mortgage-to-household income ratios than used in traditional mortgages. "The rationale for altering the income eligibility is that, in comparison to suburban households, urban households can substitute walking and public transit for automobile payments, including both capital costs and operating costs" (Nelson, 2000). Additionally, the Federal Transit Agency includes land use policies and the containment of sprawl in its "2007 New Starts Evaluation and Rating Process" (Federal Transit Authority, 2006). The foundation of this experimental policy effectively demonstrates the central hypothesis of this study: that higher densities, positively impacted by UCPs, increase the rates of transit use and supply.

To accompany the expected increases in density demand, "such [urban containment] policies are typically accompanied by 'upzoning' whereby land zoned formerly at one level of development intensity is changed to allow for a higher density" (Nelson, 2000). This is an important point since higher densities are crucial to supporting and expanding public transit systems. Higher densities, along with increased land use mixing and other expected impacts of UCPs, should have a positive impact on public transit use and supply by providing the necessary population density and subsequent urban mix of land uses. The strategic adoption of complementary strategies, such as increased and improved transit service, may also add to the positive impact to UCPs. While substantial literature exists regarding the varying impacts of UCPs, none to date explore their relationship with public transit.

Prior Research

Determining the relationship between UCPs and transit requires a review of several associated relationships. The first relationship that must be explored is that of UCPs on land development outcomes. Rodriguez et al. (2006) correctly state that "expectations about the impact of containment policies on travel patterns begin by understanding the land market" (p.

1880). This refers simply to the concept of supply and demand when supply, at least in the short term, is limited. Constraining the supply of developable land to a specific geographical area causes demand for that land to grow and eventually causes the price, or value, of land within that area to increase. Assuming adequate densities to meet demand are permitted, development pressures increase the densities required for the economic feasibility of new projects.

Literature focusing on the impacts of containment policies on land markets and other urban factors began in the early 1980s, including Nelson's research of Portland, Oregon's policies and their effect on urban land development (Wassmer, 2006). Studies by Landis (1986), Nelson (1986), and Knaap et al. (1992) effectively demonstrate containment policies' positive impact on land values. The link between UCPs and higher population densities is validated by ECO Northwest et al. (1991), Phillips and Goodstein (2000), and Pendall and Fulton (2002). Pendall and Fulton (2002) present the most comprehensive review of urban containment policy research and include numerous conclusions and policy questions. Several interesting conclusions are that UCPs can lead to higher densities, but may also encourage "leap frog" development that many urban areas don't adequately plan for. Additionally, UCPs prove more effective when the controls are tighter and coordinated at a regional scale, as opposed to only at the local level.

Rodriguez et al.'s (2006) recent study is perhaps the most relevant piece of literature to date due to its analysis of the overall transportation implications of UCPs in the largest 25 U.S. metropolitan areas. It concluded that UCPs tend to increase population density over time at a decreasing rate, but also increase VMT and worsen congestion in some metropolitan areas. These results support the hypothesis that UCPs may positively impact public transit use and supply by increasing density and the cost of automobile travel.

With a firm understanding of UCPs' positive impacts on density, it is a logical extension to expect that those impacts should also be seen in measures complementary to higher density; namely the use and supply of public transit. Research regarding the factors involved in transit use generally fall into two categories: 1) descriptive research based on travelers' attitudes and perceptions, and 2) causal research that analyzes system, environmental, and behavioral characteristics related to transit use (Taylor and Fink, 2002). While both types of research offer insight into this topic, causal studies are of particular relevance to this study because they tend to be empirically robust and produce more generalized results.

Pushkarev and Zupan's (1977) study of 105 urbanized areas in 1960 and 1970 implies that policies to increase density can also increase transit use. Similarly, Newman and Kenworthy (1996) found the same positive linear relationship between density and transit use in Melbourne, Australia, using data from 1986. Rosenbloom and Clifton (1996) found that both density and city population were directly proportional to transit use in the US. However, the trend was shown to be greater in larger cities, regardless of density. They attribute this to several possibilities, including more transit service in larger cities and the use of population and employment clusters.

Additionally, the positive impact of density on transit use is shown in several studies by Cervero (1996), Frank and Pivo (1994), and Apogee/Hagler and Baily (1998). Johnson (2003) also found that density of larger areas in the Twin Cities may be more influential than density at the neighborhood level, which supports this study's use of metropolitan level data.

Spillar and Rutherford (1998) detected a positive impact of density on transit use that plateaus inside the density range of twenty to thirty people per acre. Ewing et al. (2002) found that "twice the proportion of residents take public transit to work in relatively non-sprawling metro areas" compared to more sprawling areas, with density being "the most widely recognized indicator of sprawl" (p. 9). This is consistent with Frank and Pivo's (1994) work, which found that population density was the most significant factor in determining mode choice.

While this study's focus is at the metropolitan scale, it is important to note that density has also been found to have impacts on transit at the neighborhood level, especially since specific neighborhood characteristics can be encouraged or regulated at the city level. Density may in fact be the most important of all built environment factors at the neighborhood level since "relatively dense neighborhoods tend to have a greater variety of land uses, shorter blocks, grid-like street patterns, sidewalk networks, and so on" (Cervero & Kockelman, 1997, p. 203). However, as Cervero and Kockelman (1997) point out, Ewing (1994) argues that most of the transportation benefits of higher densities may in fact be due to mixed land uses, which typically exist in areas of higher density.

Unfortunately, nearly all studies of the built environment's effect on transportation outcomes use cross-sectional data and cannot determine causality (Handy et al. 2005). Additionally, transit specific studies typically suffer from data issues, only analyze unlinked trips, focus on only one mode of transit, or focus only on type of trip, such as work trips (Taylor and Fink, 2002).

While UCPs are shown to increase density through land constraint and its effects on demand, it is also likely that in some metropolitan areas policy decisions are made to increase and improve transit services. Assuming one of the goals of UCP adoption is to reduce VMT or personal vehicle trips in an effort to improve air quality, these policy decisions act as complementary strategies. Perhaps falling outside the realm of the free market, the policies still may result in increased transit use and supply. Unfortunately, this concept has not been explored in the literature to date, but would most certainly add to the empirical understanding of UCPs' total impacts.

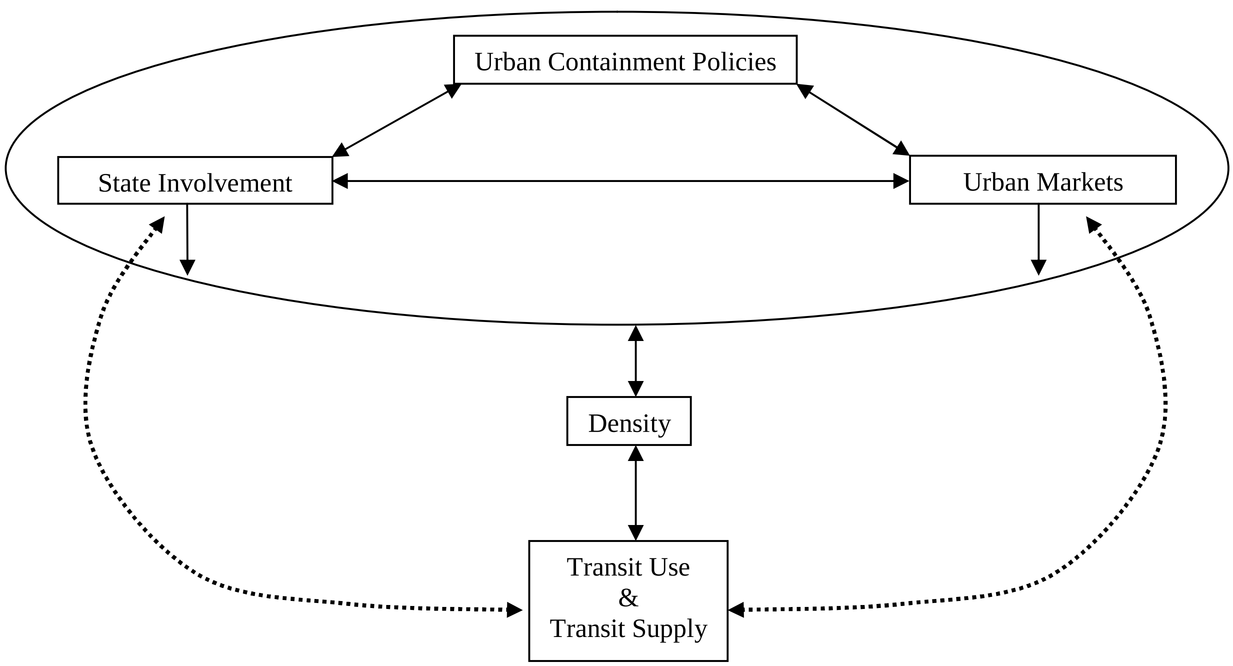
No public transit systems in the United States operate without some level of subsidy. Therefore, transit supply is not merely a function of demand, but also local and federal policies. Assuming practical policies, however, Pushkarev and Zupan (1982) showed that the rate of population density increase needed to support additional supply was actually less than the associated increase in supply. For example, they state that a "minimum service" of 20 buses per day requires at least four dwelling units per acres, and a "frequent service" of 120 buses per day requires at least fifteen dwelling units per acre. The comparison of growth rates of density to bus supply, 1:1.8, demonstrates the ability of increasing population density to create a higher rate of growth in transit supply.

The majority of research analyzing the impact of transit on urban form is focused on rail transit, but "case studies of Ottawa-Carleton, Canada, and Curitiba, Brazil, clearly show that busways that provide service comparable to rail systems can influence urban form" (Federal Transit Agency, 2006, p. 26). This possibility is important since the majority of transit supply in the US is in the form of bus service. However, it is important to note rail transit's positive impact on property values, which may increase demand for higher density development. This impact is shown in research in Portland (Al-Mosaind et al., 1993), Boston (Armstrong, 1994), Philadelphia (Voith, 1993), Alexandria (Rybeck, 1981), and other studies as well. Additionally, transit can enable a city to use market forces to build up densities near stations where most services are located (Newman & Kenworthy, 1996). This is most commonly referred to as transit-oriented development (TOD), and is increasing in popularity across the country.

Research Approach

The analytical framework provided in Figure 1 outlines the foundation for this research. This framework highlights three factors that influence transit outcomes: local adoption of UCPs, state-level urban containment policy requirements, and the function of urban markets. The arrows between these factors represent their interconnectedness. Adoption of UCPs at the local level is estimated to impact the urban land market, primarily through increased prices. State mandates are expected to impact the local adoptions of UCPs and urban markets. Urban markets are expected to impact UCPs and state involvement since failures in those markets are often the impetus for local and state policy formulation.

Figure 1. Conceptual model of urban containment policies and transit



The dashed arrows signify the indirect influence state involvement and urban markets may have on transit use and supply separate from their impacts through density. The arrows are bi-directions to display the influence of previous transit outcomes on urban markets and policy-making at the state and local level. The solid, bi-directional arrow between density and transit outcomes reflects the simultaneous relationship between the two, as changes in density may impact transit outcomes and transit outcomes may impact density.

Data

The data used for this research is taken almost entirely from Rodriguez et al. (2006), which provides a detailed description and review of the data. It is constrained to the largest 25 metropolitan areas in the US from 1984 to 1994 (T = 11 years). The presence, age, and extent of UCPs relies on Pendall's (1999, 2000) national survey of more than 1,500 local governments in the largest 25 metropolitan areas. Metropolitan statistical areas (MSA) and consolidated MSAs (CMSA) boundaries are based on 1990 delineations. The survey achieved a 77 percent response rate that included 1,168 local governments, which represented 83 percent of the population of the survey area and 32 percent of the total 1990 US population.

Knowing the year of adoption of containment policies permits a longitudinal analysis that includes the influence of policies' ages. However, the data does not discern if local governments had adopted and rescinded UCPs before the study period. Rather than using a binary measurement of the presence of UCPs, the data permits the calculation of a population-weighted percentage of each MSA covered by a policy. The total population and percentage of population covered by an urban containment policy at the beginning, middle and end of the study period is shown in Table 1.

Data on the existence of state-level legislation requiring UCPs by year is taken from a collection of existing literature (Burby & May, 1997; Burby et al., 2001; Carruthers, 2002; Nelson, 1999; Zovanyi, 1998). Four states fall under the category of requiring some level of

UCPs during the study period: Florida, Georgia, Maryland, and Washington. All of the data was updated with the most current information available regarding UCPs during the study period. The resulting sample includes local governments in 16 states and the District of Columbia.

The density variable is derived using population data for each metropolitan area from the US Census Bureau and land consumption data from the national resources inventory (NRI)[2]. The population data is based on the fixed MSA/PMSA boundary from 1984. Density is calculated as the population divided by the amount of built-up land area, excluding water bodies.

The key transit data for this study measure transit ridership and supply. Ridership data is taken from the TTI urban mobility study and is presented as annual non-linked passenger trips. Transit supply data relies on data from the National Transit Database (NTD) and processed by the Florida Transportation Information System (FTIS) through its Integrated National Transit Database Analysis System (INTDAS). Supply data is presented as annual fixed-route revenue miles per capita. Specific modes captured in the data include motorbus, heavy rail, light rail, cable car, trolley bus, and automated guideway. The resulting sample includes 138 transit agencies.

Automobile infrastructure and transit use data relies on data collected by the Texas Transportation Institute (TTI) for its annual urban mobility reports from 1982 to 1994. Population density is calculated as population divided by developed land area using data from the US Census Bureau and the National Resources Inventory (NRI) survey. Urban market attribute data relies on multiple sources including the US Department of Commerce, NRI, US Department of Agriculture, and the TTI urban mobility study.

Table 1. Total metropolitan area population and percentage of population covered by self-reported UCPs

Metropolitan Area	1984 Total population (000s)	1984 Percentage of population with UCP	1989 Total population (000s)	1989 Percentage of population with UCP	1994 Total population (000s)	1994 Percentage of population with UCP
Atlanta	2378.9	0.0	2788.6	0.0	3190.6	0.0
Boston	2244.7	38.3	2360.6	38.3	2452.3	38.3
Baltimore	3739.5	10.8	3792.3	13.1	3788.3	13.8
Chicago	6076.9	8.3	6071.9	13.6	6241.2	14.2
Cincinnati	1411.1	0.5	1447.7	0.5	1497.3	15.4
Cleveland	1872.6	0.0	1833.5	0.0	1851.9	0.0
Dallas	2227.5	0.0	2508.7	0.0	2769.5	0.0
Denver	1575.2	2.7	1612.5	2.7	1790.7	21.2
Detroit	4313.6	7.4	4370.6	8.6	4517.8	11.7
Houston	3182.1	0.0	3229.3	0.0	3620.1	0.0
Kansas City	1470.7	0.9	1554.4	1.8	1641.0	1.8
Los Angeles	8041.7	9.9	8793.7	10.7	9048.1	12.5
Miami	1755.6	100.0	1908.9	100.0	2028.6	100.0
Milwaukee	1384.9	12.3	1421.6	12.3	1459.3	14.8
Minneapolis	2232.3	4.3	2432.8	5.9	2605.9	5.9
New York	8452.5	3.0	8567.4	5.7	8592.5	7.3
Philadelphia	4742.5	20.0	4861.6	20.0	4888.3	30.0
Phoenix	1737.0	9.6	2101.8	9.6	2419.4	9.6
Pittsburgh	2160.4	7.9	2060.2	7.9	2047.1	10.3
San Diego[a]	2066.4	0.6	2444.4	0.6	2626.9	0.6
San Francisco	1550.1	7.7	1601.1	8.4	1637.0	15.3
Seattle[b]	1696.2	0.0	1922.6	0.0	2105.7	0.0
St Louis	1821.7	0.0	1872.5	0.0	2480.2	0.0
Tampa	1825.8	100.0	2039.3	100.0	2154.0	100.0
Washington, DC[c]	3521.9	2.9	3948.6	5.1	4185.2	5.7

[a] San Diego may have had a larger percentage of its population covered by an urban containment policy, specifically its tier system.
[b] Although Seattle is listed as having 0 percent population with containment policies during the study period based on the survey data, others suggest that King County adopted an urban growth boundary as early as 1985. Seattle has also been considered an example of a strong-accommodating containment framework with a regional planning component (Nelson and Dawkins, 2004).
[c] Washington, DC may have had a larger percentage of its population covered by UCPs in Montgomery County, Maryland, that may not be captured in the survey.

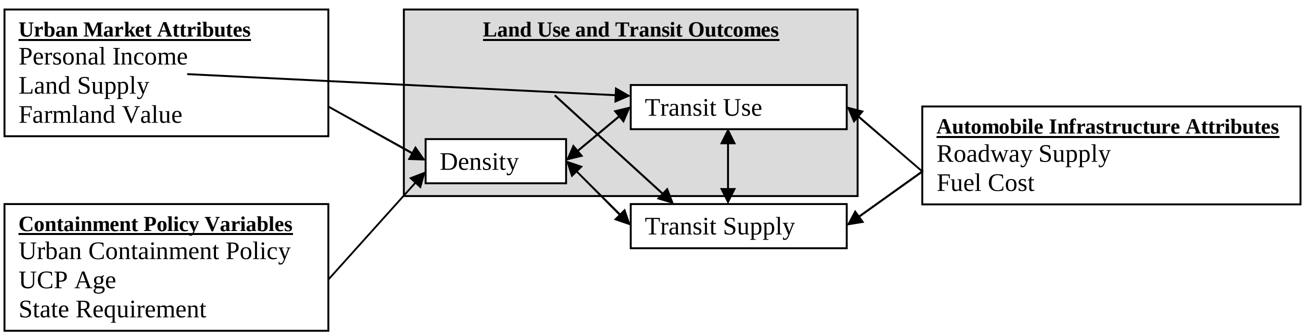
Methodology

The simultaneous relationships between density, transit use, and transit supply require a modeling framework that captures each effect at once. A 3SLS simultaneous estimation model consisting of three separate equations is used to capture these effects (Figure 2). Density, transit use, and transit supply are dependent variables for each model, respectively.

The model permits the interpretation of UCPs' indirect impacts on transit use and supply through their impacts on density, by both local policies and state involvement. Exogenous variables are controlled for under the headings of urban market and automobile infrastructure variables. Dummy variable regression is also used to capture the fixed effects of individual years and metropolitan areas. Complete variable descriptions and their summary statistics are listed in Table 2.

The expected relationships between each variable in each model are listed in Table 3. Based on Pendall and Martin's (2002) work, *UCP_Cov* is expected to be positively related to *Density*, as higher percentages of population covered by UCPs imply greater regional coordination. Similarly, *Years_UCP* and *State* are expected to positively impact *Density*. The expectation of *Density* to positively impact transit use and supply, based on existing literature,

Figure 2. Modeling framework of containment policies, land development and transit outcomes



translates into an expectation that urban containment policy variables also have a positive impact on *TransitU* and *TransitS*.

Considering the expectation that any changes in population density and their associated effects require several years or more to fully develop, it would be ideal to use a significant lag – 3 to 10 years – for the explanatory variables in each equation. Given the limited number of years available for analysis, however, only one or two year lags were plausible. The analysis and figures given in this study use a one year lag. A two year lag was also calculated and produced nearly identical results.

Table 2. Variable Descriptions

		Mean	Std Dev	Min	Max
Land use and transportation-related variables					
$Density_{it\ (fixed)}$	Population over built-up area using fixed pop and metropolitan area boundary (persons/acre)	6.45	3.71	2.96	21.23
$TransitU_{it}$	Annual transit trips per unit of area (acre)				
$TransitS_{it}$	Annual transit fixed route revenue miles (1,000s)	16031.61	15296.76	4143.68	69870.80
Urban containment policy variables					
UCP_Cov_{it}	Percentage of metropolitan area with containment policy, weighted by the 1990 population in each jurisdiction within the MSA	14.72	26.06	0.00	100.00
$Years\_UCP_{it}$	Average age of UCPs per metropolitan area, if UCPs are present	10.44	9.07	0.00	40.00
$Years\_UCP_{it}^2$	The square of $Years\_UCP_{it}$	191.13	286.44	0.00	1600.00
$State_{it}$	Presence of state UCP-related legislation (1=yes, 0=no)	0.12	0.33	0.00	1.00
Urban market variables					
$Income_{it}$	Per capita 1997 personal annual income in metropolitan area ($1,000)	16.36	4.86	8.74	32.32
$Non\text{-}builtLand_{it}$	Metropolitan area land undeveloped (1,000,000 acres, excluding water bodies)	1.71	1.08	0.30	5.58
$FarmldValue_{it}$	Mean value per acre of land in farms ($1,000)	2.64	3.52	0.40	45.85
Automobile infrastructure variables					
$Fuel_{it}$	Average cost of gasoline per gallon in MSA ($)	0.86	0.13	0.55	1.12
$Freeway_{it}$	Number of freeway lane-miles per 100 residents	0.74	0.28	0.23	1.59
$Arterial_{it}$	Number of arterial lane-miles per 100 residents	1.05	0.33	0.48	2.01

Notes: Summary statistics calculated for each metropolitan area-year (N = 275), metropolitan area (N = 25), years (N = 11). All variables change with time and are measured for each metropolitan area i in year t. Variables derived from the NRI (*Density*, *Non-builtLand*) and the Census of Agriculture (*FarmldValue*) are interpolated for the years between measurements. Variables measured in dollar units are adjusted to 1997 dollars based on the consumer price index (CPI) for each metropolitan area (Rodriguez et al, 2006).

Table 3. Expected relationships

	Density	Transit Use	Transit Supply
Density and transit variables			
$Density_{it\ (fixed)}$	-----	+	+
$TransitU_{it}$	+	-----	+
$TransitS_{it}$	+	+	-----
Urban containment policy variables			
UCP_Cov_{it}	+	-----	-----
$Years\_UCP_{it}$	+	-----	-----
$Years\_UCP_{it}^{2}$	-	-----	-----
$State_{it}$	+	-----	-----
Urban market variables			
$Income_{it}$	-	-	-
$Non\text{-}builtLand_{it}$	-	-----	-----
$FarmldValue_{it}$	+	-----	-----
Automobile infrastructure variables			
$Fuel_{it}$	-----	+	+
$Freeway_{it}$	-----	-	-
$Arterial_{it}$	-----	+	+

TransitU and *TransitS* are expected to have a mutual gain relationship and positively impact each other. Additional per capita supply of transit most likely increases the mode's overall accessibility and viability as a transportation option. This increased accessibility attracts riders who were previously using other modes and induces all transit riders to make more trips. Similarly, additional per capita transit ridership demonstrates greater demand for transit and its overall viability to policy makers and funding agencies, encouraging increased investment in transit supply.

Income is expected to be negatively related to *Density*, *TransitU* and *TransitS*. Higher median incomes translate into greater land consumption per capita and higher automobile ownership rates, which in turn lead to lower population density, transit use, and transit supply. Similarly, *Non-builtLand* is expected to be negatively related to *Density* as a larger supply of developable land drives down the price of land and reduces the market demand to build at greater densities. Much of the developable land left available in many metropolitan areas is farmland.

FarmldValue is expected to be positively related to *Density* as the resulting higher price of land for development increases the market demand for greater development densities, both on the urban fringe and in infill areas. Additionally, higher farm land values may represent more valuable, high-yield crops that discourage a change in land use.

Fuel is expected to be positively related to both *TransitU* and *TransitS*. Higher fuel prices increase the cost of using private vehicles as a transportation mode, reducing its accessibility and attractiveness. Private vehicle users who are unwilling to pay the additional cost of that mode will transfer to other modes, including transit. The increased demand for transit, as discussed above, should eventually increase transit supply.

Freeway is expected to be negatively related to both *TransitU* and *TransitS*, as higher rates of freeways in a metropolitan area increases the accessibility of private vehicles and perhaps indicate a more unbalanced funding commitment to highway construction over transit. Arterial is expected to be positively related to both *TransitU* and *TransitS*, as higher rates of arterials are typical of higher density development patterns.

The relationships between Density, TransitU, and TransitS are expressed by the following equations:

$$\ln Density_{it} = \alpha^{Density} + \gamma_1 \cdot \ln TransitU_{it} + \gamma_2 \cdot \ln TransitS_{it} + \sum_j \beta_j \cdot X_{jit} + \sum_{t-1}^{T} \theta_t^{Density} + \sum_i^{N-1} c_i^{Density} + \varepsilon_{it}^{Density}$$

$$\ln TransitU_{it} = \alpha^{TransitU} + \gamma_1 \cdot \ln Density_{it} + \gamma_2 \cdot \ln TransitS_{it} + \sum_j \beta_j \cdot X_{kit} + \sum_{t-1}^{T} \theta_t^{TransiU} + \sum_i^{N-1} c_i^{TransitU} + \varepsilon_{it}^{TransitU}$$

$$\ln TransitS_{it} = \alpha^{TransitS} + \gamma_1 \cdot \ln Density_{it} + \gamma_2 \cdot \ln TransitU_{it} + \sum_j \beta_j \cdot X_{kit} + \sum_{t-1}^{T} \theta_t^{TransiS} + \sum_i^{N-1} c_i^{TransitS} + \varepsilon_{it}^{TransitS}$$

where, *i* extends over all metropolitan areas (N = 25); *t* extends over the 11 years (1984 to 1994); for each equation α represents the constant; γ represents the estimated coefficients for the endogenous variables; β represents the estimated coefficients for the exogenous variables; θ represents the temporal effects; c represents the unit effects, and ε represents the error terms.

The set of exogenous variables for each equation is:

$$\sum_j X_{jit} = X_{it}^{UCP} + X_{it}^{Years\_UCP} + X_{it}^{Years\_UCP^2} + X_{it}^{State} + \ln X_{it}^{Income} + \ln X_{it}^{Non-builtLand} + \ln X_{it}^{FarmldValue}$$

$$\sum_j X_{kit} = X_{it}^{Income} + X_{it}^{Fuel} + X_{it}^{Freeway} X_{it}^{Arterial}$$

Concerns are raised by Brindle (1994) and others about using the same data set as the numerator of the dependent variable and the denominator of one or more independent variables. However, the modeling choice to employ such tactics in this research is based on the fact that the significance of statistical relationships is not biased and there is adequate theory to resist using alternative means.

One option is to use only raw transit use and supply data instead of per capita rates, and to include metropolitan area into the model as a control for size. However, area is not an accurate measure of size in relation to transit. For example, in 1984 the Atlanta metropolitan area had nearly the same population as the Baltimore metropolitan area, but nearly twice the area. Similarly, in the same year the Atlanta and Chicago metropolitan areas had similar areas, but Chicago had nearly three times the population. Therefore considering that transit use, and to perhaps a lesser extent transit supply, is based on potential riders, area does not prove an adequate proxy for population.

Results and Discussion

The results of each 3SLS model are shown in Table 4. Each model demonstrates very good fit, with R-squares of 0.99 (*Density* model), 0.93 (*TransitU* model) and 0.99 (*TransitS* model). An F-test was done for both sets of dummy variables in each equation. The tests indicate that a fixed-effects approach is appropriate for both years and metropolitan areas[1].

Looking specifically at the *Density* model, the coefficient for *UCP_Cov* indicates that a higher weighted percentage of UCPs in a metropolitan area is related to higher population density. A 10 percent increase in the weighted percentage of UCPs in a metropolitan area is related to a 1.1 percent increase in population density, representing an elasticity of 0.11.

The coefficient for *Years_UCP* indicates that the greater the average age of UCPs in a metropolitan area, the higher the population density. However, the negative coefficient for $Years\_UCP^2$ indicates that the effect of urban containment policy age on population density is in fact non-linear. Therefore the positive impact of average age of UCPs on population density decreases over time. Considering this diminishing impact, a 10 percent increase in the weighted percentage of UCPs in a metropolitan area is related to a 4.4 percent increase in population density, representing an elasticity of 0.44.

Contrary to the research hypothesis, state involvement is not significant in the model and has a negative coefficient. This is consistent with Carruthers' (2002) conclusion that none of the four states with state involvement included in this study positively impacted population density. This may point to the differing levels of strength and implementation of UCPs within each state.

Looking next at the *TransitU* model, the relationship between population density and transit use is consistent with the original hypothesis: higher population density is directly related to higher transit use per capita. The indirect relationship between the urban containment policy variables and transit use is calculated by multiplying their impacts on population density by population density's impact on transit use. Following this formula, a 10 percent increase in the weighted percentage of UCPs in a metropolitan area is related to a 0.7% increase in annual non-

Table 4. 3SLS fixed effects estimates of density, transit use and transit supply equations.

	Density			Transit Use			Transit Supply		
	Coefficient		*T*-statistic	Coefficient		*T*-statistic	Coefficient		*T*-statistic
Dependent Variables									
Ln(Density)	-----		-----	0.579	***	2.94	-0.556	***	-11.37
Ln(TransitU)	0.053	***	4.19	-----		-----	0.044	**	2.28
Ln(TransitS)	-0.307	***	-8.45	0.774	***	3.98			
Urban containment policy variables									
UCP	0.001	***	2.69	-----		-----	-----		-----
Years_UCP	0.005	*	1.90	-----		-----	-----		-----
Years_UCP^2	-0.000	**	-2.13	-----		-----	-----		-----
State	-0.022		-1.60	-----		-----	-----		-----
Urban market Variables									
Ln(Income)	-0.427	***	-4.07	0.470		0.92	-0.574	***	-3.78
Ln(Non-builtLand)	-0.766	***	-9.73	-----		-----	-----		-----
Ln(FarmldValue)	0.0496	***	2.56	-----		-----	-----		-----
Automobile infrastructure variables									
Ln(Fuel)	-----		-----	0.602	**	2.35	-0.030		-0.39
Ln(Freeway)	-----		-----	0.845	***	5.42	0.046		0.94
Ln(Arterial)	-----		-----	0.490	**	2.34	0.061		0.95
Constant	5.634	***	12.65	-9.467	***	-3.74	11.531	***	32.4
N	250			250			250		
R-square	0.992			0.939			0.992		
Degrees of freedom	208			205			205		

Note: *, ** and *** denote statistical significance at 90, 95 and 99 percent levels of confidence.

linked passenger trips per capita, representing an elasticity of 0.07. The results also indicate that annual non-linked passenger trips per capita increase 2.5 percent for every 10 years of average time since the UCPs were implemented, representing an elasticity of 0.25.

Looking next at the *TransitS* model, the relationship between population density and transit use is not consistent with the original hypothesis. Instead, higher population density is directly related to less transit supply per capita. A 10 percent increase in the weighted percentage of UCPs in a metropolitan area is related to a 0.6% decrease in annual fixed-route revenue miles per capita, representing an elasticity of -0.06. The results also indicate that annual fixed-route revenue miles per capita decrease 2.4 percent for every 10 years of average time since the UCPs were implemented, representing an elasticity of -0.24.

There are at least two possible reasons for the negative impact of UCPs on transit supply. First, the vast majority of transit supply in lower density areas consists of motor bus service. Lower density areas tend to be much more geographically dispersed, requiring less efficient routes that run longer miles to serve fewer riders than their higher density counterparts. Conversely, higher density areas "allow transit operators to provide the same quality and quantity of service with fewer vehicles, and fewer driver hours" (Federal Transit Authority, 1996, p. 11). This phenomenon may cause the data to express more transit supply per capita in less dense areas.

Second, even in higher density areas, transit supply often has some amount of excess capacity. Considering the marginal effect of UCPs on transit use, it is unlikely that they are significant enough to require additional transit supply to the system. Therefore, every new rider resulting from UCPs actually reduces the per capita transit supply by increasing the denominator – persons – without changing the numerator – fixed route revenue miles. So higher densities may result in more efficient transit systems by adding more riders without, at least for some period, requiring an increase in supply.

Although the focus of this study is on UCPs' impact on transit use and supply, other interesting relationships can be reported. As expected, *Income* has highly significant negative impacts on *Density* and *TransitS*. A 10 percent increase in income is related to a 4.3 percent decrease in density and a 5.7 percent decrease in per capita transit supply. Interestingly, *Income* was not significant in the *TransitU* equation, although its effect may be masked by the inclusion of *Density*.

Also as expected, *Non-builtLand* has a highly significant negative impact on *Density*, supporting the hypothesis that increased land supply reduces density through cheaper land prices. A 10 percent increase in non-built land is related to a 7.7 percent decrease in density. Conversely, *FarmldValue* has a highly significant positive impact on *Density*, supporting the hypothesis that higher valued farm land reduces the land supply, increasing the market pressure for higher development densities. A 10 percent increase in farmland value is related to a 0.5 percent increase in density.

The automobile infrastructure variables provided mixed results. While *Fuel* is not significant in the *TransitS* model, it has a significant positive impact on *TransitU*. The latter supports the hypothesis that higher fuel costs may drive travelers to alternative modes. A 10 percent increase in fuel price is related to a 6.0 percent increase in transit use. Interestingly, *Freeway* ran counter to its hypothesized effect in the *TransitU* model and was not significant in the *TransitS* model. A 10 percent increase in per capita freeway lane-miles is related to an 8.5 percent increase in per capita transit use.

This is not expected since increased per capita freeway lane-miles would increase the utility of the private automobile through greater accessibility and mobility. This concept is supported by Rodriguez et al. (2006), who found a 10 percent increase in freeway density to related to a 0.99 percent increase in VMT. The other vehicle infrastructure variable – *Arterial* – displayed the expected significant positive impact on *TransitU*. A 10 percent increase in per capita arterial lane-miles is related to a 4.9 percent increase in per capita transit use.

To summarize, the results display mixed results compared to expectations. While UCPs are shown to have a positive impact on density and transit use, they are negatively related to transit supply. All of the urban market variables displayed their expected results, consistent with the literature and theory. The automobile infrastructure variables also displayed expected results, except for freeway density, which actually had a positive impact on transit use.

Conclusions and Limitations

Although the primary goal of UCPs is often to encourage more efficient development patterns and services provision, this research analyzed the seldom discussed impact of UCPs on transit use and supply. The analysis suggests that the existence of UCPs at the local level is related to higher development densities, transit use, and transit supply at the metropolitan area. Results also show that the age of UCPs have influence, although that influence decreases over time. While UCPs showed significant impacts, state involvement did not show the significant impacts expected. It is important to note that UCPs' impact on transit use was relatively small. Thus, UCPs should not be viewed by policy-makers and urban planners as a significant tool in the transit planning process. Instead, UCPs may play a limited role along side other policy instruments in the effort to increase transportation options and create more sustainable transportation systems.

Admittedly, this research includes multiple limitations. Nelson and Dawkins (2004) classify UCPs as one of four types: weak-restrictive, strong-restrictive, weak-accommodating, or strong-accommodating. This study does not account for these differing levels of strength or the level of implementation of UCPs within each metropolitan area. This is a key point in terms of this study's impact on policy analysis. While some urban containment polices are too weak or accommodating to produce measurable results, even strong policies are intrinsically tied to their effective implementation. The availability of data to control for such factors as strength and implementation would allow for a more rigorous analysis.

Another limitation is the study period used in this analysis. The majority of the study years (8 of 11) fall in a period of disinvestments and general apathy towards higher development density and transit at the federal, state and local level. The adoption of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1992 represented a major shift in the methods and funds available for transit financing. Future study of this topic that included data from the following 11 years (1995 – 2006) would surely provide interesting comparative results.

Notes

1. An F-test was conducted for each equation and both dummy variable types: year and city. Each test had a p-value of less than 0.05 except the test for the transit supply equation and year dummy variable. However, its p-value of 0.055 was considered adequate for this study's purposes.
2. The NRI data are estimates. As quality control, the error (standard deviation) for all MSAs included in our study had to be less than 10 percent of the estimated mean. For each metropolitan area, on average, the standard deviation is within 2 percent of the mean estimate.

References

Al-Mosaind, M. A., Dueker, K. J., & Strathman, J. G. (1993). Light rail transit stations and property values: a hedonic price approach. *Transportation Research Record 1400,* 90–94.

Apogee Research. (1998). The effects of urban form on travel and emissions: a review and synthesis of the literature. Draft Report, No. HBIX Reference C611-005. Environmental Protection Agency, Washington, DC.

Armstrong, R. J., Jr. (1994, January). Impacts of commuter rail service as reflected in single-family residential property values. Paper presented at the annual meeting of the Transportation Research Board, Washington, D.C.

Brindle, R. (1994). Lies, damned lies, and "auto dependency." *Australasian Transport Research Forum*, 19, 117 – 131.

Burby, R. J., & May, P. J. (1997) Making Governments Plan: State Experiments in Managing Land Use. Baltimore, MD: Johns Hopkins University Press.

Burby, R. J., Nelson, A. C., Dennis, P., & Handmer, J. (2001). Urban containment policy and exposure to natural hazards: Is there a connection? *Journal of Environmental Planning and Management,* 44, 475.

Carruthers, J. I. (2002). The impacts of state growth management programmes: A comparative analysis. *Urban Studies,* 39, 1959-1982.

Cervero, R. (1996). Mixed land-uses and commuting: evidence from the American Housing Survey. *Transportation Research Part A – Policy and Practice* 30(5), 361-377.

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research – D*, 45(3), 199-219.

ECO Northwest, David J. Newton Associates & MLP Associates. (1991). Urban growth management study: case studies report. Oregon Department of Land Conservation and Development, Portland, Oregon.

Ewing, R. (1994). Characteristics, causes, and effects of sprawl: a literature review. *Environmental and Urban Issues*, 11(2), 1-15.

Ewing, R., Pendall, R., & Chen, D. (2002). *Measuring sprawl and its impact*. Washington, DC: Smart Growth America.

Federal Transit Administration. (1996). *Transit and urban form*. (TCRP Report 16). Washington, DC: National Academy Press.

Federal Transit Administration. (2006). Project Evaluation. Retrieved April 10, 2006, from http://www.fta.dot.gov/16237_ENG_HTML.htm

Frank, L. and Pivo, G. (1994). The impacts of mixed use and density on the utilization of three modes of travel: the single occupant vehicle, transit, and walking. *Transportation Research Record* 1466, 44–52.

Holtzclaw, J. (1990, April). Explaining urban density and transit impacts on auto use. Paper Presented to the State of California Energy Resources Conservation and Development Commission by Natural Resources Defense Council and the Sierra Club.

Johnson, A. (2003). Bus transit and land use: illuminating the interaction. *Journal of Public Transportation*, 6, 4, 21 – 40.

Khattak, A., Rodriguez, D. (2005). Travel behavoir in neo-traditional neighborhood Developments : A case study in USA. *Transportation Research A*, 39, 6: 481 – 500.

Landis, J. D. (1986). Land regulation and the price of new housing: lessons from three California cities. *Journal of the American Planning Association*, 52, 9-21.

Nelson, A. (1986). Using land markets to evaluate urban containment programs. *Journal of the American Planning Association*, 52, 156-171.

Nelson, A. (1999). Comparing states with and without growth management analysis based on indicators with policy implications. *Land Use Policy*, 16, 121-127.

Nelson, A. (2000, May) Effects of urban containment on housing prices and landowner behavior. *Land Lines Newsletter*, 12(3): Retrieved April 15, 2006, from http://www.lincolninst.edu/pubs/pub-detail.asp?id=298

Nelson, A., & Dawkins, C. (2004). Urban containment in the United States: history, models and techniques for regional and metropolitan growth management. American Planning Association. Chicago, Illinois

Newman, P., & Kenworthy, J. (1996). The land use-transport connection. *Land Use Policy*, 13, 1, 1 – 22.

Pendall, R. (1999). Do land-use controls cause sprawl? *Environment and Planning B,* 26, 555-571.

Pendall, R. (2000). Local sand use regulation and the chain of exclusion. *Journal of the American Planning Association*, 66, 125-142.

Pendall, R. & Fulton, W. (2002). Holding the line: UCPs in the United States. Discussion paper, Brookings Institution Center on Urban and Metropolitan Policy, Washington, DC.

Phillips, J. & Goodstein, E. (2000). Growth management and housing prices: the case of Portland, Oregon. *Contemporary Economic Policy*, 18, 334-344.

Pushkarev, B.S. & Zupan, J.M. (1977). *Public transportation and land use policy*. Ontario, Canada: Indiana University Press.

Pushkarev, B.S. & Zupan, J.M. (1982).Where transit works: urban densities for public transportation. In H.S. Levinsion & R.A. Weant (Eds.),*Urban Transportation: Perspectives and Prospects*. CT: Eno Foundation for Transportation.

Rodriguez, D., Targa, F., & Aytur, S. (2006). Transportation implications of urban containment policies: A study of the largest 25 U.S. metropolitan areas. *Urban Studies*, 43, 10, 1879-1897.

Rosenbloom, S. & Clifton, K. (1996). The puzzle of income, race, and density: preliminary evidence on transit use from the 1991 American housing survey. Journal of Public Transportation, 1, 1, 87 – 102.

Rybeck, W. (1981). Metrorail impacts on Washington area land values. Washington, DC, Subcommittee on the City, Committee on Banking, Finance, and Urban Affairs, U.S. House of Representatives.

Spillar, R. & Rutherford, G. (1998). *The effects of population density and income on per capita transit ridership in Western American cities*. ITE 1990 Compendium of Technical Papers, Institute of Transportation Engineers, Washington, D.C.

Taylor, B. & Fink, C. (2002). *The factors influencing transit ridership: A review and analysis of the ridership literature*. Los Angeles: University of California at Los Angeles.

Voith, R. (1993). Changing capitalization of CBD-oriented transportation systems: evidence from Philadelphia, 1970–1988. *Journal of Urban Economics*, 33, 361–376.

Wassmer, R. (2006). The influence of local urban containment and statewide growth management policies on the size of United States urban areas. *Journal of Regional Science*, February: pp. 25-67.

Zovanyi, G. (1998). Growth management for a sustainable future: ecological sustainability as the new growth management focus for the 21st century. Westport, CT, Praeger.